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SECTION II: CHAPTER 5
NOISE

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NOISE

A. INTRODUCTION

THRESHOLD AND CRITERION LEVELS

Title 8, California Code of Regulations (T8-CCR), Group 15. Occupational Noise, Article 105, establishes the minimum requirements for controlling occupation exposures to noise. All places of employment are covered by this regulation except Agriculture, Construction and Oil and Gas Drilling and Servicing Operations which are only exempt from the provisions of T8-CCR 5097 through 5100.

Sound measuring and calibration equipment are used to evaluate noise exposures and/or determine the feasibility of engineering controls. Sound level meters are used to screen the workplace to determine if additional measurements are needed to evaluate employee exposure, substantiate measurements obtained when using dosimeters, perform special measurements, e.g. for impact or impulse noise and to assist in determining the feasibility of engineering controls. Dosimeters are used to measure and determine an employee's 8-hour time-weighted exposure. Octave band analyzers are primarily used to evaluate the characteristics of the noise source and assist in determining the feasibility of engineering controls. Calibrators are used to insure that the equipment is measuring within their appropriate specifications.

All sound measuring and calibration equipment must, at a minimum, meet the requirements of the American National Standard Institute (ANSI) standard for Type 1 or Type 2 meters. The accuracy of an ANSI Type 1 meter is $\pm$ 1 dB while the accuracy of a Type 2 meter is $\pm$ 2 dB.

A ***threshold level*** is the sound pressure level, as measured in decibels (dB) on the A-scale (dBA) at slow response, at which a personal noise dosimeter begins to integrate noise to determine a noise exposure. The threshold level is set at 80 dBA to determine compliance with T8-CCR 5097, Hearing Conservation Program requirements. A threshold level is set at 90 dBA to determine compliance with T8-CCR 5096, feasible administrative or engineering control requirements. A noise dosimeter is designed to capture and integrate into the computation of noise dose, all noise in an employee's hearing zone that exceeds the specified threshold level. Sound levels below the set threshold level are not included in the computation of noise dose.

The ***criterion level*** is the continuous equivalent A-weighted sound pressure level at slow response, that constitutes 100% of the 8-hour time-weighted average permissible exposure limit (PEL) of 90 dBA.

T8-CCR 5097 requires employers to administer a continuing, effective hearing conservation program for all employees whose noise exposures equal or exceed an 8-hour TWA of 85 dBA which is equivalent to 50 percent of the PEL. All continuous, intermittent, and impulsive sound levels from 80 dB to 130 dB are included in the measurement of dose. .

Measurements taken with an 80 dBA threshold dosimeter will show a higher noise dose than an instrument with a threshold of 90 dBA if both instruments are used side-by-side to evaluate the same noise exposure (see Table II:5-1).

Dosimeters can be used to calculate both the continuous equivalent A-weighted sound level (LA) and the 8-hour time-weighted average (TWA) for the time period sampled, using the following formulas:

$L_A = 16.61 \text{ Log}_{10} [(D)/(12.5 T)] + 90$ (Equation. II:5-1a)

$TWA = 16.61 \text{ Log}_{10} [(D)/(100)] + 90$ (Equation. II:5-1b)

where:

L_A = continuous equivalent dBA for the time period sampled.
D = dosimeter readout in percent noise dose.
T = sampling time in hours.
TWA = 8-hour time-weighted average in decibels.

Equation II:5-1b is used for enforcement purposes, and equation II:5-1a can be used to assist in evaluating hearing protectors and engineering controls.

EXCHANGE RATE

The exchange rate is the increase or decrease in decibels corresponding to twice (or half) the noise dose. The exchange rate as defined in T8-CCR is 5 dB which means, assuming that duration is held constant, that a sound pressure level at 90 dB is twice that at 85 dB. It should be noted that the setting of the dosemeter exchange rates may be changed to 3 dB, 4 dB or 5 dB. Only instruments using a 5 dB exchange rate may be used for compliance measurements. Compliance personnel should be aware that noise dosimeters used by the Department of Defense use a 4 dB exchange rate, while instruments used by the Environmental Protection Agency and most foreign governments use a 3 dB exchange rate.

The hypothetical exposure situations shown in Table II:5-1 illustrate the relationship between criterion level, threshold, and exchange rate and show the importance of using a dosimeter with an 80 dBA threshold to characterize an employee's noise exposure. A dosimeter with a 90 dBA threshold will not capture any noise below 90 dBA, and will thus give a readout of 0% even if the employee being measured is actually being exposed to 89 dBA for 8 hours i.e., to 87% of the allowable noise dose over any 8-hour period, therefore an 80 dBA dosimeter must be used to determine the noise exposure below 90 dBA.

TABLE II:5-1.
DOSIMETER READOUT, IN PERCENT OF MEASURED DOSE

Exposure Conditions	Dosimeter - 90 dBA Threshold	Dosimeter - 80 dBA Threshold
90 dBA for 8 hours	100.0%	100.0%
89 dBA for 8 hours	0.0%	87.0%
85 dBA for 8 hours	0.0%	50.0%
80 dBA for 8 hours	0.0%	25.0%
79 dBA for 8 hours	0.0%	0.0%
90 dBA for 4 hours plus 80 dBA for 4 hours	50.0%	62.5%
90 dBA for 7 hours plus 89 dBA for 4 hours	87.5%	98.4%
100 dBA for 2 hours plus 89 dBA for 6 hours	100.0%	165.3%

* Assumes 5 dB exchange rate, 90 dBA PEL, ideal threshold activation, and continuous sound levels.

B. EFFECTS

AUDITORY EFFECTS

Chronic noise-induced hearing loss is a permanent sensorineural condition that cannot be treated medically. It is initially characterized by a declining sensitivity to high-frequency sounds, usually at frequencies above 2,000 Hz.

Exposure of a person with normal hearing to workplace noise at levels equal to or exceeding the PEL may cause a shift in the worker's hearing threshold. Such a shift is called a standard or significant threshold shift and is defined as a change in hearing thresholds of an average 10 dB or more at 2,000, 3,000, and 4,000 Hertz (Hz) in either ear. Workers experiencing significant threshold shifts are required by T8-CCR 5098 (b)(2) to be fitted with hearing protectors and to be trained in their use in accordance with T8-CCR 5099 (a)(3)(B).

EXTRA-AUDITORY EFFECTS

There are a number of effects, other than hearing loss that are triggered by exposure to noise. These effects include:

* Interferes with speech
* Causes a stress reaction
* Interferes with sleep
* Lowers morale
* Reduces efficiency
* Causes annoyance
* Interferes with concentration
* Causes fatigue.

C. INSTRUMENT PERFORMANCE

EFFECTS OF THE ENVIRONMENT

Temperature, humidity, atmospheric pressure, wind, and dust can affect the performance of all noise-measuring instruments and their readings. Magnetic fields can also affect the performance of instruments.

Temperature

Sound-measuring equipment should perform within design specifications over an ambient temperature range of -20°F to 140°F (-29°C to 60°C). If the temperature at the measurement site is outside this range, refer to the manufacturer's specifications to determine if the sound level meter or dosimeter is capable of performing properly.

Sound-measuring instruments must not be stored in automobiles during hot or cold weather because this may cause warm-up drift, moisture condensation, and weakened batteries which can affect instrument performance.

Humidity

Sound measuring instruments will perform accurately as long as moisture does not condense or deposit on the microphone diaphragm. If excessive moisture or rain is a problem in a given exposure situation, the Senior Industrial Hygienist and/or the CALICO Laboratory Assistant should be consulted.

Atmospheric Pressure

Both atmospheric pressure and temperature affect the output of sound level calibrators with atmospheric pressure the most important. When checking an acoustical calibrator, always apply the corrections for atmospheric pressure that are specified in the manufacturer's instruction manual. Typical effects of atmospheric pressure changes on sound pressure reading are shown in Table II:5-2.

TABLE II:5-2.
APPROXIMATE EFFECTS OF PRESSURE ON SOUND PRESSURE READINGS

SEA LEVEL REFERENCE	ATMOSPHERES	PSIA	INCHES Hg	dB CORRECTION
15,000 FEET	0.564	8.29	16.88	+ 2. 5
10,000 FEET	0.687	10.00	20.57	+ 1.6
5, 000 FEET	0.83	12.2	24.89	+ 0.8
SEA LEVEL	1.0	14.7	30	0.0
- 16 FEET	1.5	22.5	45	- 1.8
- 33 FEET	2	30	60	- 3.0
- 66 FEET	3	45	90	- 4.8
- 100 FEET	4	60	120	- 6.0
- 133 FEET	5	75	150	- 7.0

Generally, altitudes higher than 10,000 feet above sea level or at locations where the work site is being maintained at greater-than-ambient pressure e.g., in underwater tunnel construction, the manufacturer's instruction should be consulted. If pressure corrections are not listed in the manufacturer's instruction then use the following equation to correct the instrument reading:

$C = 10 \log [(460 + t)/528] (30/B)$ (Equation. II:5-2)

where:

C = correction, in decibels, to be added to or subtracted from the measured sound level,

t = temperature in degrees Fahrenheit, and

B = barometric pressure in inches of mercury.

NOTE: For high altitude locations, C will be positive; in hyperbaric conditions, C will be negative.

Wind

Wind blowing across the microphone of the dosimeter or sound level meter produces turbulence, which may cause a positive error in the measurement. A wind screen must be used for all outdoor measurements and whenever there is significant air movement inside a building e.g., when cooling fans are in use or wind is gusting through open windows. The Senior Industrial Hygienist and/or the CALICO Laboratory Assistant should be consulted if extreme air turbulence is encountered at the measurement site. To protect the microphone diaphragm from airborne contaminants and to avoid errors caused by wind, a wind screen should always be used on all measuring instruments.

Chemical Contaminants

Various types of dust, fumes, mists, vapors and droplets depositing or condensing on the microphone diaphragm may cause a negative error in the measurement and have a detrimental effect on the microphone. A wind screen should always be used to protect the microphone while conducting measurements. The Senior Industrial Hygienist and/or CALICO Laboratory should be consulted for advice about special instrumentation if it is planned to use the instrument in a contaminated environment without a wind screen.

Magnetic Fields

Certain equipment and operations, such as heat sealers, induction furnaces, generators, transformers, electromagnets, arc welding, and radio transmitters generate electromagnetic fields that can induce current in the electronic circuitry of sound level meters and noise dosimeters and cause erratic readings. Although most new instruments have shielding, if sound level meters or dosimeters must be used near such devices or operations, the extent of the field's interference should be determined by consulting the manufacturer's instructions, Senior Industrial Hygienist or the CALICO Laboratory.

EFFECTS OF SOUND

The effects of microphone placement and orientation are negligible when using sound measuring equipment equipped with omnidirectional microphones in a typical reverberant environment. If the measurement site is nonreverberant and/or the noise source is highly directional, the manufacturer's literature should be consulted to determine proper microphone placement and orientation.

D. NOISE MEASUREMENTS

INSTRUMENTS

Noise dosimeters, sound level meters, octave-band analyzers and calibrators are available. The uses and limitations of each kind of instrument are discussed below.

Noise Dosimeter

Noise dosimeters used by CAL/OSHA meet the American National Standards Institute (ANSI) Standard S1.25-1978, "Specifications for Personal Noise Dosimeters," which set performance and accuracy tolerances. The dosimeter must have a 5 dB exchange rate, use a 90 dBA criterion level, be set at slow response, and use either an 80 dBA or 90 dBA threshold gates. Some available dosimeters simultaneously measure exposures using the 80 dBA and 90 dBA threshold gates, while others may only be set at 80 dBA or 90 dBA threshold gates. Compliance personnel will assure that measurements are taken with the appropriate instruments to obtain exposure doses for both the 80 dBA and 90 dBA thresholds.

Sound Level Meter

All sound level meters used by compliance personnel meet ANSI Standard S1.4-1971 (R1976) or S1.4-1983, "Specifications for Sound Level Meters," which set performance and accuracy tolerances. Sound level meters include instruments meeting the requirements for ANSI Type 1 or Type 2 meters. Sound level meters generally used for:

* Spot-check noise dosimeter performance.
* Screen an employee's noise exposure to determine if additional evaluation is necessary.
* Assist to identify and evaluate noise output of individual sources.
* Aid in the determination of the feasibility of engineering controls.
* To evaluate hearing protectors (See section F).
* Evaluate employee exposure to impact and/or impulse noise, if the SLM is equipped with the proper detection device.

T8-CCR 5096 (d) indicates that the exposure to impact or impulse noise *should* not exceed 140 dB peak sound pressure level. This is a permissive statement in the regulation and can not be cited. Impact and impulse noise is incorporated by a noise dosimeter as part of the total exposure.

Sound measuring equipment must be used in a manner to effectively measure employee exposures and/or substantiate the feasibility of engineering controls. The generally acceptable procedure to be followed for all sound level measurements are:

* Microphone used to evaluate employee exposure shall be omnidirectional.

* Sound level meters shall be calibrated before and after monitoring.
* Microphones used to evaluate employee exposure should be placed in employee's hearing zone, i.e., one-foot spherical zone about the head.

Microphones, cables and/or equipment shall not be positioned in a manner that could lead to entanglement which could cause an injury to employees or compliance personnel or in a position that would cause damage to the equipment. If a danger of entanglement exists, compliance personnel should contact the Senior Industrial Hygienist prior to continuing the inspection.

* Measurements shall be taken on the side of the employee’s head having the highest noise exposure.
* Manufacturer’s instructions shall be used when taking measurements in a nonreverberant environment.
* A-weighted network at slow response shall be used exclusively for compliance.
* All continuous, intermittent, impact and impulse noise is included in the data collected using a dosimeter and computed as part of the total noise dose.

In general, a 90 dBA threshold dosimeter is necessary to establish compliance with the PEL. In unusual situations it may be necessary to rely on results obtained with an 80-dBA threshold dosimeter. If compliance personnel wish to use the data from an 80 dBA dosimeter for the basis of a citation, they must consult with the Senior Industrial Hygienist to determine whether there is sufficient evidence to demonstrate noncompliance.

Octave-Band Noise Analyzers

The Type 1 sound level meters with built-in octave band analysis capability are available to compliance personnel. Octave-band analyzers can be used to determine feasibility of engineering controls and to evaluate the effectiveness of hearing protectors. Octave-band analyzers separate noise into its component frequencies. Most of the octave-band analyzers available to compliance staff contain filter sets which filter noise into geometric mean frequencies, often called “preferred mid-band frequencies” at 31.5, 63, 125, 250, 500, 1,000, 2,000, 4,000, 8,000, and 16,000 Hz.

The special signature of a given noise can be obtained by taking sound level meter readings at each of these frequency settings assuming that the noise is fairly constant over time. The results indicate the predominate noise level or radiated sound power, in each of the specific octave-bands. Octave-band noise analyzers can assist in determining the adequacy of various types of frequency-dependent noise controls. High noise levels determined in the lower frequency ranges could indicate that the predominate source is due to vibration. High noise levels determined in the upper frequencies could be related to motor bearing squeal. Octave-band analyzers can also be used to determine the efficacy of hearing protectors because they can measure the amount of attenuation offered by the protectors in the octave-bands responsible for most of the sound energy in a given situation. The Senior Industrial Hygienist can provide assistance in the use of octave-band analyzers to determine the feasibility of engineering controls and evaluate hearing protectors.

ACCURACY

Readings with an ANSI Type 2 sound level meter and readings with a noise dosimeter are considered to have an accuracy of ±2 dBA. Readings with an ANSI Type 1 sound level meter have an accuracy of ±1 dBA.

CALIBRATION

Noise equipment must be calibrated in accordance with the manufacturer's instructions before and after each day or monitoring period use and whenever the temperature or relative humidity changes significantly. Noise monitoring equipment, including calibrators, are to be periodically evaluated and certified by the CALICO Laboratory as compliant with ANSI standards. The CALICO Laboratory should be contacted to obtain a schedule for periodic evaluation and certification.

SAMPLING STRATEGY

Compliance personnel shall conduct a walkaround survey to determine if conditions warrant a noise survey and to develop a noise sampling strategy.

Walkaround Survey

Compliance personnel shall conduct a screening for noise exposures using calibrated sound level meters. Measurements and estimates of exposure duration will be made to determine the need for a more complete evaluation. In addition to a sound level meter, a dosimeter may be useful to project a potential exposure above the PEL.

Workshift Sampling

If the walkaround survey results indicate that the 8-hour time-weighted average exposure may exceed the 85 dBA action level or the 90 dBA PEL, noise measurements shall be obtained from a representative number of employees for each job classification potentially overexposed. A dosimeter with a 90 dBA and an 80 dBA threshold gate shall be used to measure the noise exposures.

The 80 dBA threshold dosimeter shall be used to determine compliance with T8-CCR 5097(a), Hearing Conservation Program and a 90 dBA threshold dosimeter shall be used to determine compliance with T8-CCR 5096(b), Exposure Limits for Noise - Feasible Engineering and Administrative Controls.

TABLE II:5-3
COMPARISON TABLE OF DURATION PER DAY IN HOURS TO ALLOWABLE SOUND LEVEL IN dBA (SLOW-RESPONSE SPL)

Duration per day, hours	Sound level, dBA, slow-response
8.0	90
6.0	92
4.0	95
2.0	100
1.0	105
0.5	110
0.25	115

Source: T8-CCR 5096

As a minimum sampling strategy, measurements shall be taken for the period of time necessary to establish an exposure above the PEL and Action Level adjusted to the lower, - 2 dBA, accuracy of the instrument.

SAMPLING PROTOCOL

Advising Employee

Compliance personnel shall inform employees of the following:

* The purpose of monitoring the noise.
* The purpose of the dosimeter.
* The dosimeter is not a recording device.
* To report any usual work activities creating unusual noise or problems wearing the dosimeter.
* To work in a normal routine manner.
* The dosimeter will not interfere with his/her normal duties.
* Not to remove the dosimeter without contacting CAL/OSHA personnel.
* Not to cover the microphone with a coat, outer garment or any other article.
* When and where the dosimeter will be removed.

Procedure

Calibrate the dosimeter and sound level meter to be used prior to starting the evaluation. The dosimeter is generally placed and clipped in an employee’s shirt pocket or onto a waistband or belt. The microphone is clipped to the employee's shirt collar at the shoulder, close to the employee's ear receiving the highest noise exposure as determined using a sound level meter. The microphone shall be placed in the vertical position to the extent practical in accordance with the manufacturer's instructions. The dosimeter, microphone and microphone cable shall be positioned and secure in a manner to avoid snagging and inconvenience to the employee.

If there is a possibility of entanglement of the dosimeter, microphone or microphone cable which could cause injury, under no circumstances shall the employee be fitted with or required to wear the equipment. Compliance personnel shall contact the Senior Industrial Hygienist prior to continuing with the evaluation.

Check the dosimeter periodically to ensure that the microphone is vertically oriented properly. Obtain and document sound level meter readings during different phases of the work performed by the employee during the shift. Take enough readings to identify work cycles. More readings should be taken when noise levels fluctuate widely to obtain a statistical distribution of the noise. Record the information required on the OSHA-92.

Some dosimeters indicate when a 115 dBA sound level has instantaneously been exceeded. This single indication is not to be used for compliance determinations.

TABLE II:5-4
CONVERSION FROM PERCENT NOISE EXPOSURE OR DOSE TO 8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL

Dose or percent	TWA (dBA)
50	85.0
55	85.7
60	86.3
65	86.9
70	87.4
75	87.9
80	88.4
85	88.8
90	89.2
95	89.6
100	90.0
105	90.4
110	90.7
115	91.1
120	91.3
125	91.6

Represents a 5 dB exchange rate and 90 dBA PEL.

Source: T8-CCR Article 105, Control of Noise Exposure, Appendix A, Table A-2

Dosimeter Reading Logic

No citations shall be issued for hearing conservation requirements or for engineering/administrative controls pursuant to T8-CCR 5097 or T8-CCR 5096 unless the lower limit of the accuracy of the instrument has been deducted from the calculated exposure. The following table provides the logic for various dosimeter readings to be used to determine if a violative condition may be cited:

TABLE II:5-5
DOSIMETER READINGS

%	80 dB(A) THRESHOLD DOSIMETER		90 dB(A) THRESHOLD DOSIMETER	
DOSE	NOISE CONTROL	HEARING CONSERVATION	NOISE CONTROL	HEARING CONSERV.
<50	IN COMPLIANCE	IN COMPLIANCE	IN COMPLIANCE	INCONCLUSIVE
50-66	IN COMPLIANCE	INSTRUMENT ACC.	IN COMPLIANCE	INSTRUMENT ACC.
>66<100	IN COMPLIANCE	VIOLATION	IN COMPLIANCE	VIOLATION
>100<132	INCONCLUSIVE	VIOLATION	INSTRUMENT ACC.	VIOLATION
>132	INCONCLUSIVE	VIOLATION	VIOLATION	VIOLATION
>264	VIOLATION	VIOLATION	VIOLATION	VIOLATION

E. ULTRASONICS

Ultrasound is high frequency sound that is inaudible to the human ear. The frequency audibility limit of the human ear is generally approximately 20 kHz. This limit is not fixed, with some individuals having the ability to hear higher frequencies and others hearing lower frequencies. The ability to hear high frequencies declines with age.

Most of the audible noise associated with ultrasonic sources, e.g., ultrasonic welders or ultrasonic cleaners, is actually comprised of subharmonics of the machine's fundamental ultrasonic frequencies. For example, many ultrasonic welders have a fundamental operating frequency of 20 kHz, a sound that is typically at the human frequency audibility limit. However, a good deal of noise is also present at 10 kHz, the first subharmonic frequency of the 20 kHz operating frequency, and is therefore audible to most persons.

APPLICABILITY OF NOISE REGULATION

T8-CCR Article 105, Control of Noise Exposures, does not directly specify a category of noise defined as ultrasonics. The T8-CCR regulations indirectly addresses ultrasonic noise because of the noise exposure measurement criterion, including the characteristics necessary for the sound level meter to meet ANSI standards and, for Type 2 meters, have a microphone with an accuracy of ± 5 to infinity at frequencies above 10,000 Hz. At 20 kHz, an A-weighted level is 10 dB below an unweighted sound pressure level. At 50 kHz, an A-weighted level is 25 dB below the corresponding unweighted level. As an example, if an A-weighted instrument is used to measure a 50 kHz, 110 dB tone, the instrument will indicate 85 dBA at which a hearing conservation program would be required.

Occasionally it may be necessary to perform specialized measurements to determine the major noise source frequently associated with ultrasonic noise to establish that engineering controls are feasible. To measure any source suspected of producing ultrasonic noise requires the use of a precision or ANSI Type 1 sound level meter equipped with a suitable microphone of adequate frequency response and a portable third-octave filter set. Compliance personnel should consult with the Senior Industrial Hygienist before attempting to monitor for ultrasonic noise.

HEALTH EFFECTS

Research indicates that ultrasonic noise has little effect on general health unless there is direct body contact with a radiating ultrasonic source. Reported cases of headache and nausea associated with airborne ultrasonic exposures appear to have been caused by high levels of audible noise from source subharmonics. The American Conference of Governmental Industrial Hygienists (ACGIH) has established permissible ultrasound exposure levels (See Table II:5-6). However, these recommended limits, set at the middle frequencies of the one-third octave bands from 10 kHz to 50 kHz, are designed to prevent possible hearing loss caused by the subharmonics of the set frequencies rather than the ultrasonic sound itself.

CONTROLS

High frequency noise is very directional and is relatively easily reflected or blocked by any type of barrier. The wavelength of a frequency of 16 kHz , for example, is about 3/4 inch, so a barrier of 1 to 2 inches is generally sufficient to reflect noise of approximately the same frequency away from a nearby worker. Such barriers are inherent in some of the machine surfaces themselves.

High frequency audible noise is also easily absorbed by any of the so-called acoustical materials e.g., glass fiber or foam, thereby preventing reflection of noise from the surface. Higher frequency sound is absorbed readily by ambient air, usually resulting in finding that the high frequency noise problem is almost certain to be a very local problem in any workplace layout.

TABLE II:5-6.
PERMISSIBLE AIRBORNE UPPER SONIC AND ULTRASOUND ACOUSTIC RADIATION EXPOSURE LEVELS

Mid-frequency of third-octave band, kHz	One-third octave band level, in dB (unweighted)
10.0	80
12.5	80
16.0	80
20.0	105
25.0	110
31.5	115
40.0	115
50.0	115

Source: American Conference of Governmental Industrial Hygienist (ACGIH) 1995.

F. NOISE INSPECTION DATA

INFORMATION TO BE COLLECTED

In addition to the information required for a health inspection, collect the following information where pertinent and where necessary to document a violation.

Employee Data

* Distance from the employee to the primary noise source(s).
* Need for the employee to be present or close to the noise field.
* Employee exposure time pattern.
* Existence of any known employee auditory problems, e.g., ear infections, ringing in the ears, or trouble with hearing after the work shift.
* Employee's opinion of the practicality of potential noise engineering controls considering machine operation.
* Hearing protection provided and any problems with its use or acceptance.
* Time since the last audiometric examination.
* Frequency of audiometric examination.
* Training in the effects of noise and use and maintenance of hearing protectors

Machine and/or Process Data

* Type of machine, and a brief description of it and/or the process, including identifying numbers, sketches, and photographs whenever possible.
* Condition of the machine, e.g., age and maintenance status.
* Machine operation, e.g., speed, cycle times, parts/minute, and materials used
* Apparent existing noise and/or vibration controls, e.g., vibration dampener, springs, acoustical insulation, enclosures used.
* Source(s) and characteristics of the noise, e.g., fan noise--discrete and broad band components, continuous or noncontinuous. Octave band analyzers, real time analyzers, and narrow band analyzers may be useful in determining sources of noise.
* Available engineering and/or administrative controls.

Building Data

* Size and shape of the room.
* Layout of equipment, work stations and break areas.
* Surface materials, e.g., ceiling/steel; walls/cinderblock; floor/concrete.
* Existing acoustical treatment.
* Potential acoustical treatment.
* Noise from other sources, i.e., spill-over noise, adding to exposure.
* Presence of barriers or enclosures.

Employer Data

- * What has been done to control the noise, e.g., have consultants been used, has plant noise been monitored, have engineering controls been recommended and installed?
- * What is planned for the future ?
- * Have administrative controls been considered, utilized and are they enforced?

Hearing Loss Data

Document the following when hearing loss is used to support a citation:

- * The amount of the threshold shift and date it was recorded.
- * Employee's exposure level.
- * Frequency and duration of employee's exposure.
- * Length of employment.
- * Explanation of any follow-up measures taken .
- * Duration of audiometric testing program .

EVALUATION OF HEARING PROTECTION

The actual effectiveness of any individual hearing protector cannot be determined under work-place conditions; however, T8-CCR require that personal hearing protection be worn to attenuate the occupational noise exposure of employees to within the limits specified in the regulation. Hearing protectors are evaluated under rigorous laboratory conditions specified by the American National Standards Institute in ANSI Z24.22-1957 (R1971) and ANSI S3.19-1974. Scientific literature indicate that laboratory-obtained real ear attenuation for hearing protectors is seldom be achieved in the work place.

Hearing Protector Attenuation

Compliance personnel shall evaluate the adequacy of a hearing protector in accordance with Article 105, Appendix E, Methods for Estimating the Adequacy of Hearing Protector Attenuation. To determine the attenuation of a hearing protector used by an employee in an actual work environment, the following steps must be taken:

- * Document the Noise Reduction Rating (NRR) identified on the protector or package.
- * To adjust for workplace conditions apply a 50% safety factor by dividing the NRR by 2.
- * If dual protection, i.e., ear plugs and muffs are worn, add 5 dB to the NRR listed for the higher-rated protector.
- * For dual protection, average the two NRRs and apply a 50 % safety factor by dividing the resultant average NRR by 2.

If a different safety factor seems to be more appropriate, the Senior Industrial Hygienist should be consulted for assistance.

Where it appears that the attenuation of the hearing protector is not sufficient to reduce employee noise exposure below the specified exposure limits listed, the employer shall be cited and advised that a greater degree of employee protection is required. The degree of employee protection afforded by the hearing protection in use is particularly important when the employees have experienced hearing impairment, or feasibility of engineering and/or administrative controls are an issue.

Figure II:5-1 gives examples of hearing protector attenuation calculations.

FIGURE II:5-1. CALCULATING HEARING PROTECTOR ATTENUATION.

Obtain the Noise Reduction Rating (NRR) for the hearing protector. Calculate the laboratory-based attenuation using this manual or use the NIOSH procedures described in the "List of Personal Hearing Protectors and Attenuation Data," HEW Publication No. 76-120, 1975, when no NRR is available for the protector. Since the noise dosimeter provides a TWA in dBA, subtract 7 dB from the NRR.

Consider the following examples:

Example 1: TWA_8 = 100 dBA
Muff type hearing protector in use with an NRR = 19 dBA
Approximate Field Attenuation is: (19dBA - 7 dBA) x 50% = 6 dBA
100 dBA TWA(8-hr) - 6 dBA = 94 dBA

Conclusion: The 8-hour time-weighted exposure is 100 dBA therefore feasible engineering and/or administrative controls must be implemented pursuant T8-CCR 5096(b). The hearing protectors can be assumed to provide an attenuation of noise down to 94 dBA. The protection provided by the hearing protectors without using the 50% safety factor, is 88 dBA. Therefore, better hearing protection is not required by the standard.

Example 2: Dual protection being used.
TWA(8-hrs) = 110 dBA
Plug type hearing protector NRR = 29 and,
Muff type hearing protector NRR = 25

a. Calculate field-adjusted NRR for the higher-rated protector:
   (29dBA - 7dBA) x 50% = 11 dBA
b. Add 5 dBA to this field-adjusted higher rated NRR: 11dBA +5 dBA = 16 dBA
c. Calculate the protected TWA-8 hrs: 110 dBA TWA (8-hr) - 16 dBA = 94 dBA

Conclusion: The 8-hour time-weighted exposure is 110 dBA therefore feasible engineering and/or administrative controls must be implemented pursuant T8-CCR 5096(b). The protected TWA-8hr can be assumed to be 94 dBA. The protected TWA-8hr, without using the 50% safety factor, is 83 dBA. Therefore, better hearing protection is not required by the standard; however, it should be recommended.

G. HEARING CONSERVATION

HEARING CONSERVATION PROGRAMS

When employees are exposed to sound levels that equal or exceed the Action Level of an 8-hour time-weighted average of 85 dBA as specified in T8-CCR 5097(a), a continuing effective hearing conservation program is required. The program must include all employees whose work brings them routinely or intermittently, into areas in which the sound levels equal or exceed the Action Level.

T8-CCR 5097(a), (b), (c), (d), (e) and (f) specifies the minimum requirements for a Hearing Conservation Program including monitoring, audiometric testing, audiogram evaluation, audiometric test requirements, and calibration of audiometers.

AUDIOMETRIC TESTING

The best way to ensure that an employer has implemented a continuing and effective hearing conservation program is evaluate the employer’s records. If exposures may equal or exceed the Action Level, the employer is required to conduct noise monitoring. When exposure equal or exceed the Action Level, the employer is required to conduct periodic audiometric testing and maintain accurate monitoring and audiometric test records as required by T8-CCR 5097(b), (c), (d) and T8-CCR 5100(a) and (b).

Audiometric tests shall be pure tone, air conducting, hearing threshold examinations at least at frequencies of 500, 1,000, 2,000, 3,000, 4,000 and 6,000 Hertz (Hz) for each ear using appropriate equipment and in a location meeting the specifications of T8-CCR. The purpose of these tests are to determine if the employee has experienced a Standard Threshold Shift (STS) or loss of hearing.

Compliance personnel will evaluate the equipment, methods and facilities used to conduct audiometric testing and examine a representative number of audiograms when conducting a noise survey. The CAL/OSHA Medical Unit may be requested to assist in the interpretation of these data.

An STS is an indicator of hearing loss. A STS is "a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2,000, 3,000, and 4,000 Hz in either ear." Figure II:5-2 shows how to compute standard threshold shifts.

H. CONTROL

Noise control should:

* Minimize sources of noise,
* Preclude the propagation, amplification, and reverberation of noise, and
* Protect workers from excessive noise.

Engineering controls include antivibration machine mountings, acoustical enclosures and equipment replacement or modification, e.g. silencers or mufflers on air powered tools Administrative practices may require shift rotation or exposure limitation.

Personal protective equipment such as ear muffs or ear plugs or both can be used and/or are required to be worn under certain conditions specified in T8-CCR. When noise exposures exceed an 8-hour time-weighted PEL of 90 dBA, feasible engineering or administrative controls must be implemented irrespective of the use of hearing protectors.

FIGURE II:5-2. COMPUTING THE STANDARD THRESHOLD SHIFT (STS)

Example 1

Frequency (Hertz)	Employee's Baseline audiogram threshold (dB)	Employee's Annual audiogram threshold (dB)	Change
500	5	5	0
1,000	5	5	0
2,000	0	10	+10
3,000	5	20	+15
4,000	10	35	+25
6,000	10	15	+5

To evaluate for an STS, only 2,000, 3,000, and 4,000 Hz, are used. The data from the employee's audiometric tests or audiograms, are compared to the employee's baseline data. The resultant comparison indicates the employee's hearing threshold values have changed, i.e., for 2,000 Hz, a + 10 dB; 3,000 Hz , a +15 dB; and, for 4,000 Hz, a + 25 dB. The values are added together and divided by 3 to obtain the average STS. Therefore:

$$STS = \frac{(10\text{ dB} + 15\text{ dB} + 25\text{ dB})}{3} = \frac{50}{3} = 16.7\text{ dB}$$

Conclusion: The calculated STS for the subject employee exceeds an average of 10 dB or more at the specified frequencies, i. e., + 16.7 dB, and therefore, it is concluded that the individual's hearing has deteriorated. The employee must be notified in writing of the results and, depending on professional discretion, the employer may elect to revise the baseline audiogram.

FIGURE II:5-2. COMPUTING THE STANDARD THRESHOLD SHIFT (CONTINUED)

Example 2

Frequency (Hertz)	Employee's Baseline audiogram threshold (dB)	Employee's Annual audiogram threshold (dB)	Change
500	5	5	0
1,000	5	0	-5
2,000	0	-10	-10
3,000	5	-5	-10
4,000	10	-5	-15
6,000	10	5	-5

Examine the values for the employee's audiogram at 2,000, 3,000, and 4,000 Hz and compare with the employee's established baseline data. The hearing threshold is lowered by - 10 dB, - 10 dB, and - 15 dB, respectively.

Thus:

$$STS = \frac{(-10 \text{ dB} - 10 \text{ dB} - 15 \text{ dB})}{3} = \frac{-35 \text{ dB}}{3} = -11.6 \text{ dB}$$

Conclusion: The STS is - 11.6 dB and it can be concluded that the employee's hearing has improved significantly. The employee will be notified of the results and, depending on professional discretion, the baseline audiogram may be revised.

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APPENDIX II:5-1. EVALUATING THE NOISE EXPOSURE OF EMPLOYEE WEARING SOUND-GENERATING HEADSET

EMPLOYEES AT RISK

Allegations of experiencing acoustic trauma to the ear and hearing loss due to noise overexposure can occur where employees wear a sound generating muff type, music headphones or insert type headphones. Clerical personnel, aircraft pilots and other cockpit personnel, air traffic controllers, reservation clerks, receptionists, and telephone operators are examples of employees exposed to high noise levels via communications headsets. Other employees may be exposed when they are permitted by their employer to wear entertainment related headphones on and when they are off work.

When wearing a sound-generating headset, the sound/noise exists predominantly between the ear drum and the headset. The sound intensity that is created by headsets inside the ear is quite different from ambient levels because of the amplification properties of the human ear.

Probe microphones and similar devices inserted into the ear allow sound levels to be measured, however, employees find this uncomfortable and object to wearing a probe for an 8-hour workday. Inserting a probe requires careful training to prevent damage to the ear drum and therefore will not be used for compliance purposes.

METHODOLOGY

A method of monitoring employee exposure without invading the ear canal has been developed. This sampling method evaluates the noise dose that an employee receives during the actual work day while wearing an insert type headset, a monaural or binaural muff, or a monaural or binaural foam headset.

Special equipment and techniques are necessary to evaluate noise exposure related to headsets. Compliance personnel are to consult with the Senior Industrial Hygienist prior to attempting to conduct such an evaluation.

In general, the technique measures the electrical signal input to the worker's headset using a Bruel & Kjaer noise dosimeter and a set of filters (audio equalizer). The filters take into account the electrical-to-acoustical conversion efficiency of the headset and the differences between the sound levels occurring in the ear canal and the free field. The method is safe, easy to operate, and convenient for field use. Current analysis indicates that the accuracy of the system is ±1.5 dB.

Prior to sampling, the actual headset or an identical model of the head set worn by the employee must be sent to a qualified laboratory to calibrate the equipment. The headset is placed on a KEMAR artificial head, which simulates the acoustic response of a median human ear. White noise is input to the headset and the transfer functions of the headset are obtained at all frequencies over the range of human hearing.

A digitally programmable one-third octave filter set (audio equalizer) is preprogrammed with the transfer functions obtained in the earlier laboratory headset evaluation. Employee monitoring can then be conducted in the workplace utilizing the sampling procedures outlined in Section II, Chapter 5.

The input signal to the employee's headset is split, with one branch going into an audio equalizer attached to a Bruel & Kjaer dosimeter, and the second branch going into the employee's headset. After the sampling period (which is normally an 8-hour workday), the employee's noise dose (in percent exposure) is recorded from the dosimeter. Any violation for employee overexposure would be cited as would any other noise exposure violation

ACOUSTIC LIMITING DEVICES

Headsets can be categorized into those without any form of acoustic limiting device, and those with some form of limiting device built into the headset. Most modern telecommunication headsets use sophisticated limiting circuits, while headsets for special applications (e.g., Walkman head-sets) do not. Headsets equipped with acoustic limiting devices have been shown to maintain exposures below the PEL. Headsets without limiting devices have, in some work environments, caused employee noise exposures to exceed the PEL.